Stimulated Raman scattering with large Raman shifts with liquid core Kagome fibers (Orale)

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Summary

Stimulated Raman scattering in photonic bandgap liquid filled fibers is known to be an attractive technique for manufacturing efficient wavelength converters. However the possible frequency shifts are limited by the spectral bandwidth of these fibers. We experimentally demonstrate that Kagome fibers allow to greatly enlarge these shifts.

Introduction

Requiring no phase matching condition, stimulated Raman scattering is a robust technique to convert any wavelength in a larger one. Typically if a pump beam is focused inside a Raman medium, stimulated Raman scattering converts the pump photons into Stokes photons at a longer wavelength. The frequency shift just depends on the selected Raman medium and can be selected among a very large panel up to a few thousands of cm^{-1}, for instance about 3200 cm^{-1} for the main Raman line of water. Raman cascades (e.g. further scattering of the Stokes photons) allow reaching larger shifts. For most materials and for low power lasers, the relatively low Raman gain limits the conversion efficiency. To circumvent this limitation, liquid filled hollow core photonic crystals were proposed [1]. The large propagation length compensates for the low gain. The guiding properties are provided by the fiber photonic crystal structure, so that the refractive index of the Raman liquid can be lower than the one of the silica, which enlarges the panel of the available liquids and thus of the Raman shifts. Conversion efficiencies larger than 70% (in terms of photons) were demonstrated. Both the pump beam frequency and the converted frequency should lie within the spectral transmission bandwidth of the fiber. The frequency position of the transmission band is adjusted by selecting the refractive index of the liquid. The limited width of the transmission band can be used to control the Raman emission by stopping the cascade to a given order [2]. Nevertheless in cases where large Raman shifts are necessary, for example to realize wavelength converters reaching the near infrared range using a pump at 532 nm, the limited bandwidth of photonic bandgap fibers is a drawback. These large shifts were nevertheless previously obtained with hollow core microstructured fibers, using total internal reflection instead of photonic bandgaps, but at the expense of a multimode propagation [3]. To reach large shifts while keeping a single mode propagation, we propose to use fibers with a Kagome structure.

Experiment

Raman converters using gas filled Kagome fibers have already been realized [4], but until now they had not been used with liquids filling their structures as described

here. Our goal was to convert a 532 nm beam from a pulsed frequency doubled microlaser up to 772 nm by using a Raman cascade in ethanol (Raman frequency shift of 2930 cm^{-1}). It delivers 560 ps pulses at a 6 kHz repetition rate. We selected a 90 cm long Kagome fiber whose core diameter is 20 µm. All wavelengths (pump at 532 nm, first and second stokes at 630 and 772 nm) lie within the transparency band of the Kagome fiber. This liquid enters the Kagome fiber owing to capillary forces. We injected the focused pump beam at the first end of the fiber. Output mean powers for the pump beam and for the Raman orders are measured by an Optical Spectrum Analyzer. In figure 1 we plotted these powers versus the power at fiber entrance.

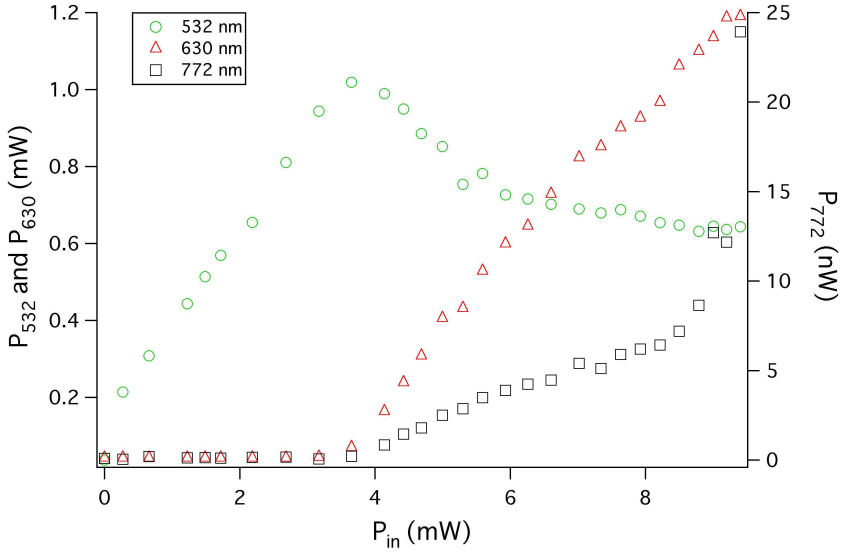

Fig. 1. Output powers versus the fiber input power; green circles and red triangles refer to the transmitted pump beam and 1st Stokes beam (left axis); black squares correspond to the 2nd Stokes order (right axis).

The pump beam at 532 nm starts to be significantly converted to the first Stokes wavelength at 630 nm for an input power of about 4 mW. This first Stokes is then converted to the Stokes at 772 nm. For this second conversion the efficiency is limited by the maximum available pump beam power.

Conclusions

We observed single mode wavelength conversion from 532 nm to 772 nm using a Raman cascade in an ethanol filled Kagome fiber. Although the conversion efficiency is limited by our pump laser power, this first demonstration clearly demonstrates the interest of Kagome fibers for wavelength conversion over large frequency ranges using liquids as Raman media.

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